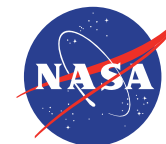


Europa Lander Mission Overview and Update

Steve Sell

15th International Planetary Probe Workshop, Boulder CO

June 2018



Jet Propulsion Laboratory
California Institute of Technology

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Predecisional information for planning and discussion only



Europa Lander Direct-to-Earth Mission Concept



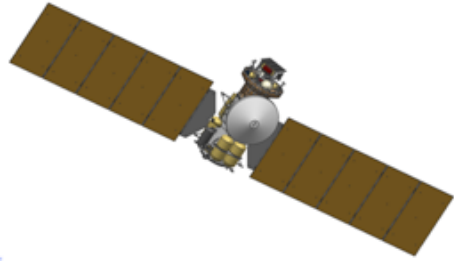
Launch

- SLS Block 1B
- Nov 2026



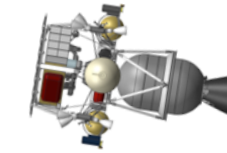
Cruise/Jovian Tour

- Jupiter Orbit Insertion: Sep 2031
- Europa Landing: 2033



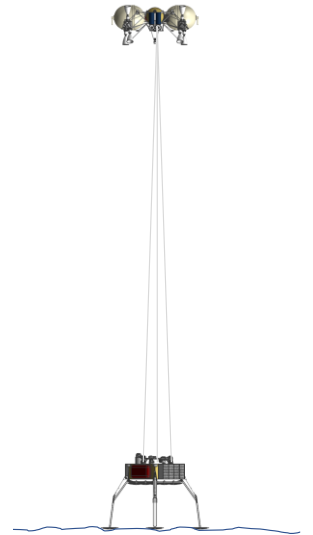
Carrier Stage

- 2.0 Mrad radiation exposure
- **Elliptical disposal orbit**



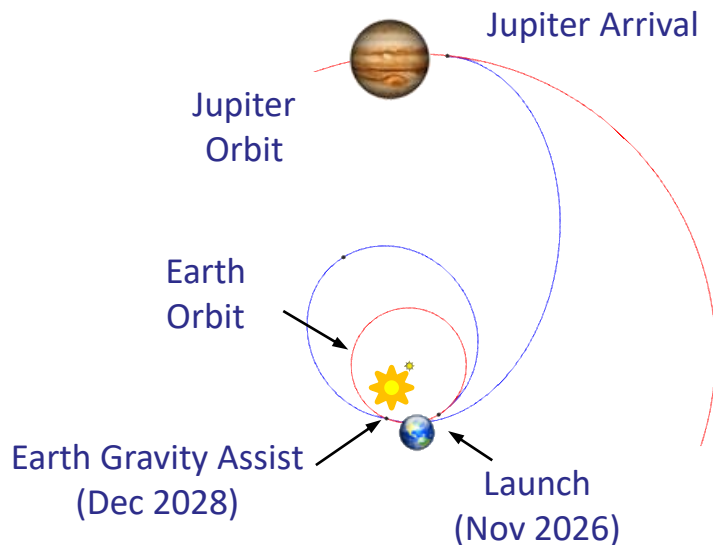
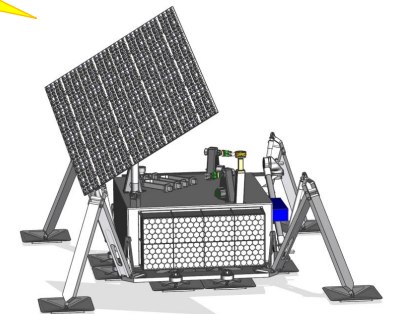
Deorbit, Descent, Landing

- Guided deorbit burn
- Sky Crane landing system
- 100-m accuracy
- **DTE tones only**



Surface Mission

- **Biosignature Science**
- 20+ days
- **3 samples from 1 trench**
- **Direct to Earth Comm or Clipper (backup)**
- **1.5 Gbit data return**
- 50 kWh battery (Useable)
- 2.0 Mrad radiation exposure





Post-MCR Design Options

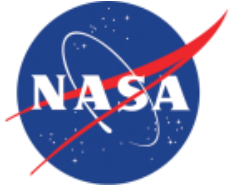
After Mission Concept Review in June 2017, team pursued three variants of the Europa Lander Mission concept to explore reduced cost

- Evolved MCR design

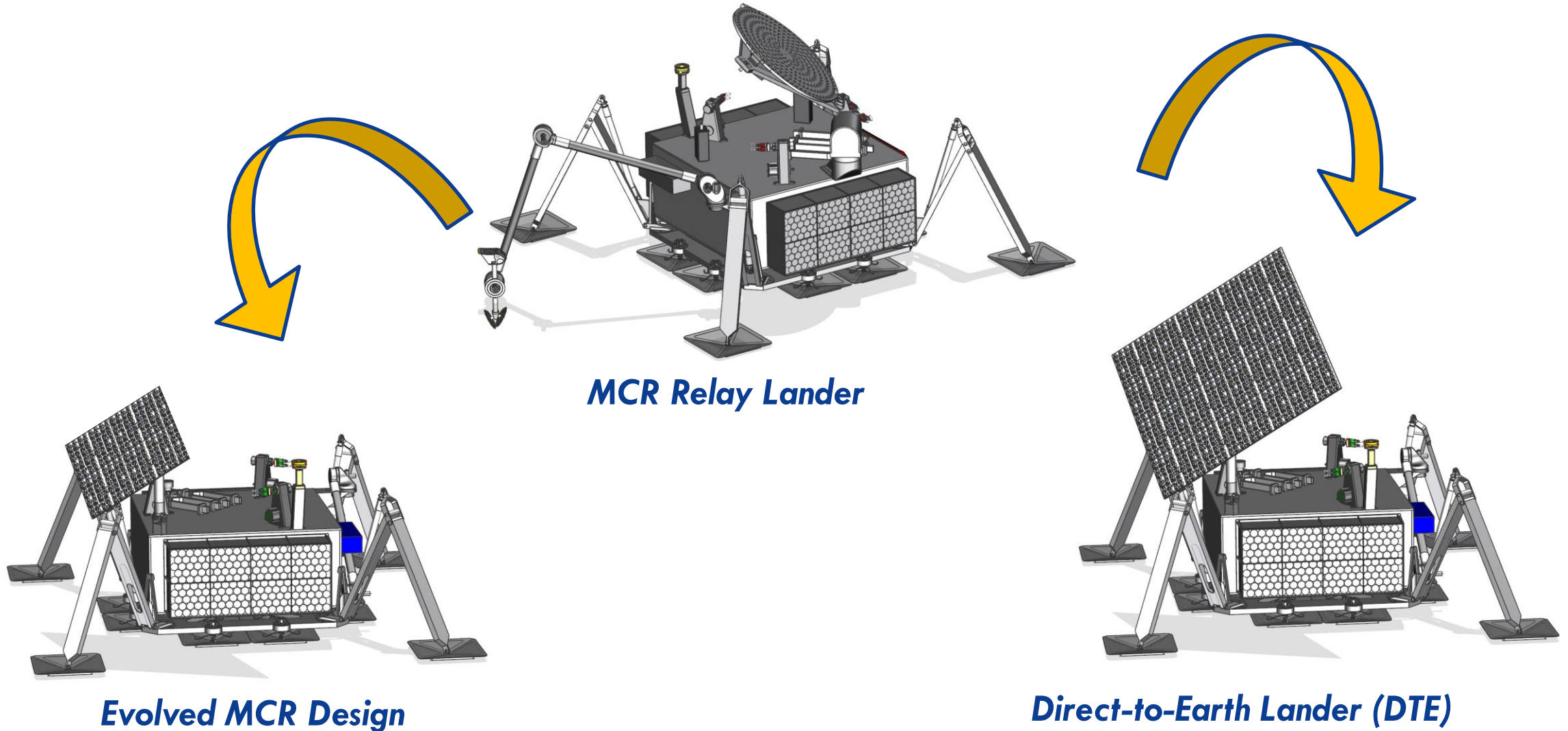
- Uses the Carrier spacecraft as a communications relay with relaxed visibility and communications cadence
- Carrier maneuvers to stable orbit after surface mission ends

- Direct To Earth

- Communication path is direct from the Lander to Earth without using the carrier spacecraft for relay
- Carrier becomes non-operational once Lander separates and is therefore abandoned in stable orbit



Considered Options



Artist's Concepts



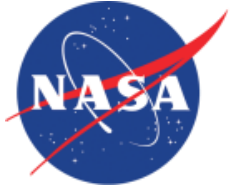
How did we reduce mass?

- The two largest drivers on the Flight System mass
 - Fuel (ΔV)
 - Power (heat and background power draw)
- The team set about ways of reducing through relaxation of requirements and mission features without sacrificing the surface mission objectives



Key Technical Changes from MCR Design (1/2)

- Changes applicable to all options (Relay and DTE Options)
 - Use re-packaged Clipper avionics on Lander for power savings
 - Re-distributed power functionality more optimally for much lower sleep power
 - Perform longer tour to save ΔV
 - Marginally increases radiation exposure, but reduces prop needed in tour
 - Landing delayed up to 1 year, depending on landing site

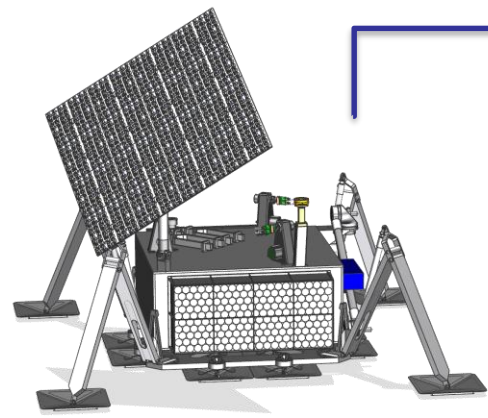
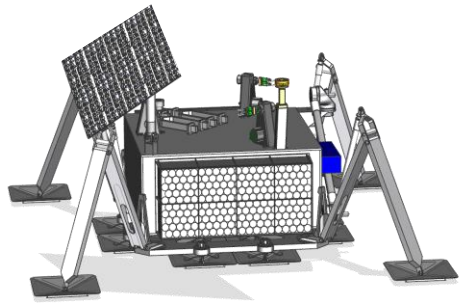
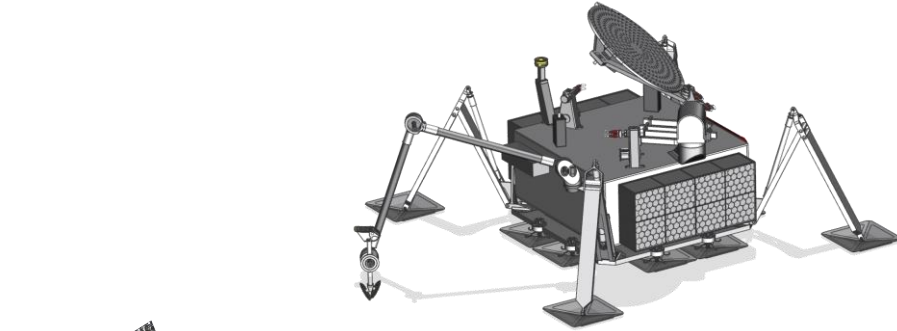


Key Technical Changes from MCR Design (2/2)

- Changes applicable to Relay Option
 - Relaxed post-touchdown communication duration requirement from 15 min to “a few seconds”
 - Relaxed TD-to-first-overflight requirement from 24 hours to up to ~3.5 days (delay is landing site dependent)
 - Added minimal DTE capability to allow health, status, backup communications with Lander during times where carrier isn’t visible
 - Carrier maneuvers to stable orbit after surface mission, but does not survive for extended future use
 - Surface communications cadence is variable depending on landing site (was forced to be 24 hour cycles in MCR design)
- Changes applicable to DTE Option
 - Primary communication is Direct-to-Earth from Lander
 - Requires high-precision antenna pointing (~0.5 deg) for communications to work
 - High-power radio amplifiers, large antenna added to Lander for DTE communications
 - Carrier is dependent on the Lander to operate
 - System is maneuvered to stable orbit prior to Lander separation
 - Abandoned in stable, non-operational state at Lander separation



Approximate Mass Comparison



Concept	Dry Launch Mass	
	kg	%Δ
MCR	5700	0%
Evolved Relay	4200	-26%
DTE	4140	-27%

Artist's Concepts

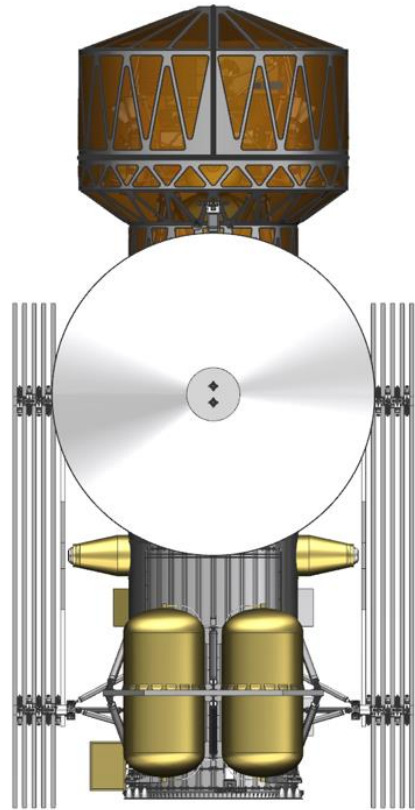


Direct To Earth Chosen as Architecture

- After careful review, the Direct To Earth architecture was chosen as the Europa Lander Mission concept to continue
 - Was the lightest of the options explored
 - Reduced complexity in the surface mission could lead to less risk of cost growth later
 - Only operating one spacecraft at a time
 - Lifetime at Europa for Carrier reduced
 - Much lower radiation total dose

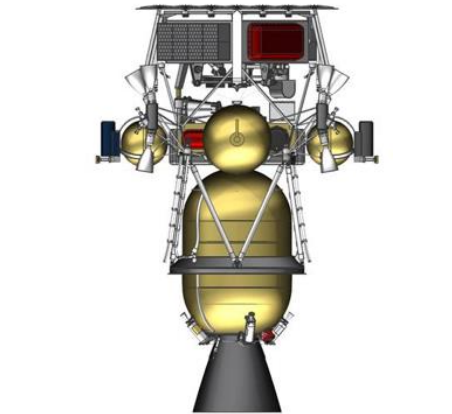


Baseline System Vehicles

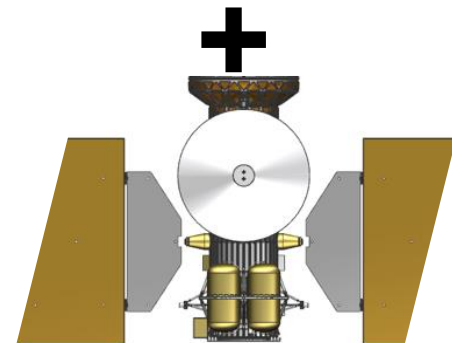


Cruise Vehicle (CV)

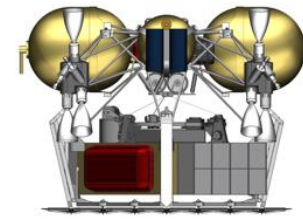
Launch Mass: 14 mt



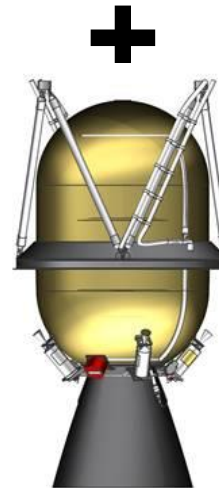
Deorbit Vehicle (DOV)



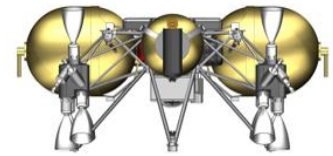
Carrier Stage (CS)



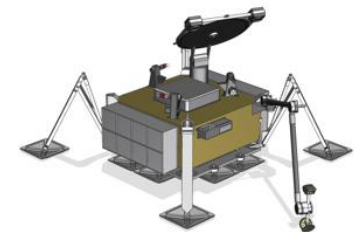
Powered Descent Vehicle (PDV)



Deorbit Stage (DOS)

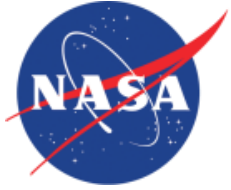


Descent Stage (DS)

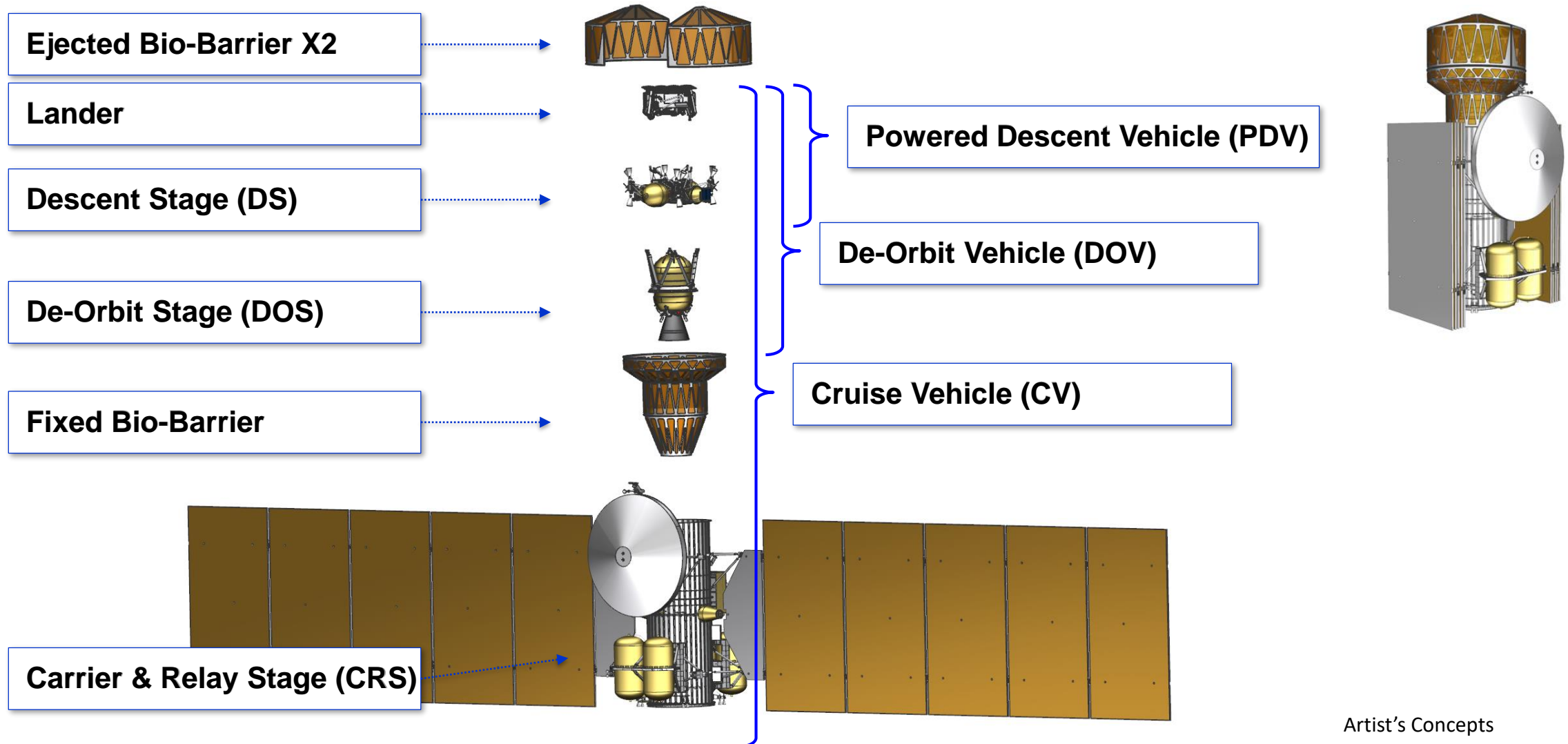


Lander

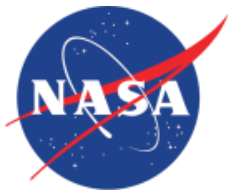
Artist's Concepts



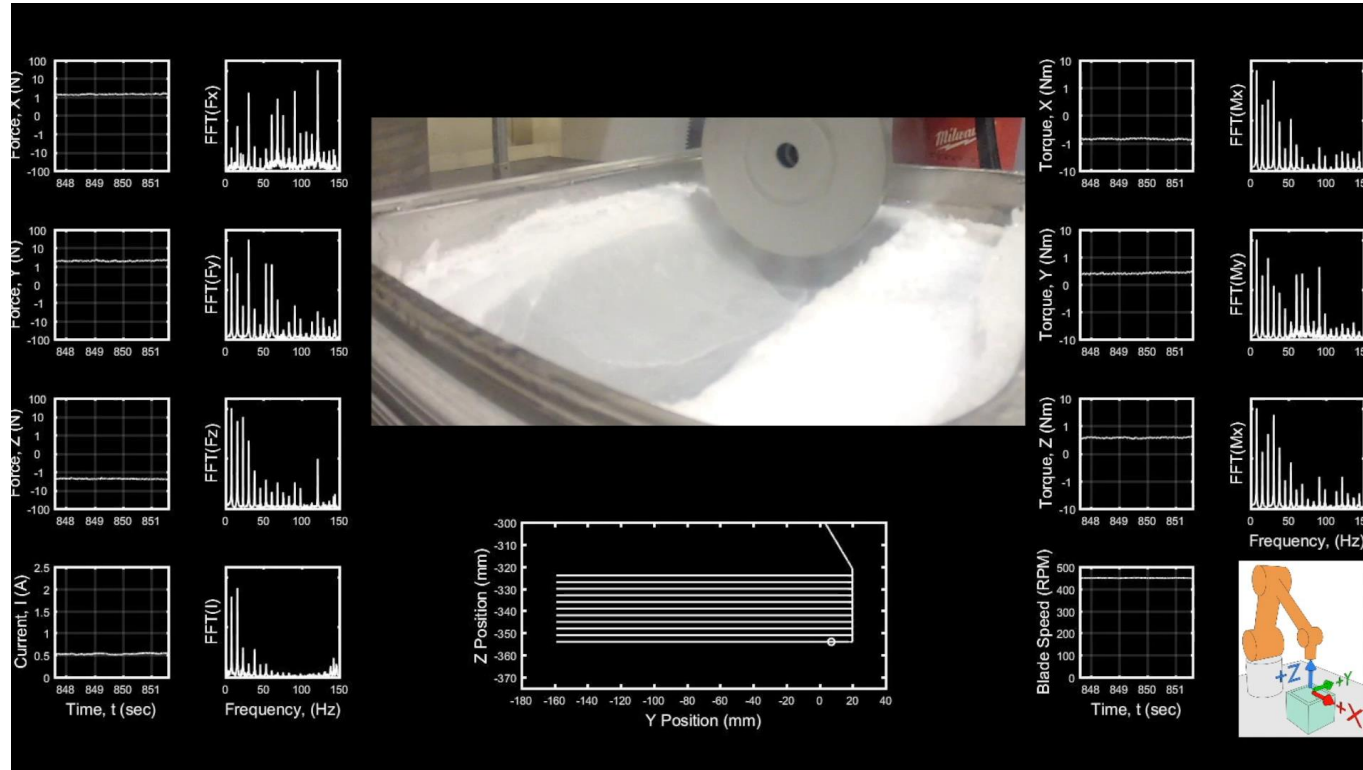
Baseline Launch Assembly



Artist's Concepts



Excavation testing



Relative Power to Excavate

300% Square-Tooth Blade
(Shaving)

250% MgSO_4 Ice 100K

200%
150% Water Ice 100K
 MgSO_4 Ice 190K

100% Cotton Ice 190K
Water Ice 190K

50%

0%

Undercutting-Toothed
Blade
(Shaving + Fracturing)



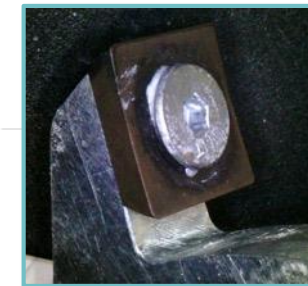
MgSO_4 Ice 100K

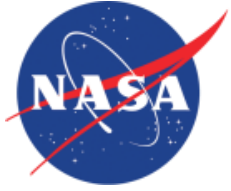
MgSO_4 Ice 190K

Cotton Ice 190K

Water Ice 100K

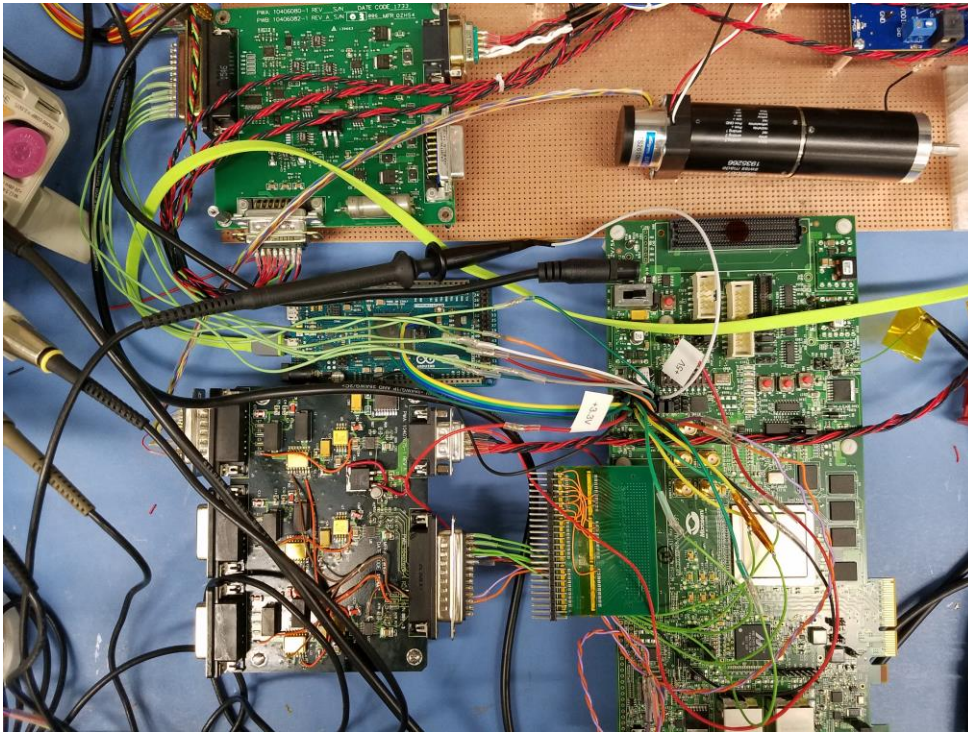
Water Ice 190K



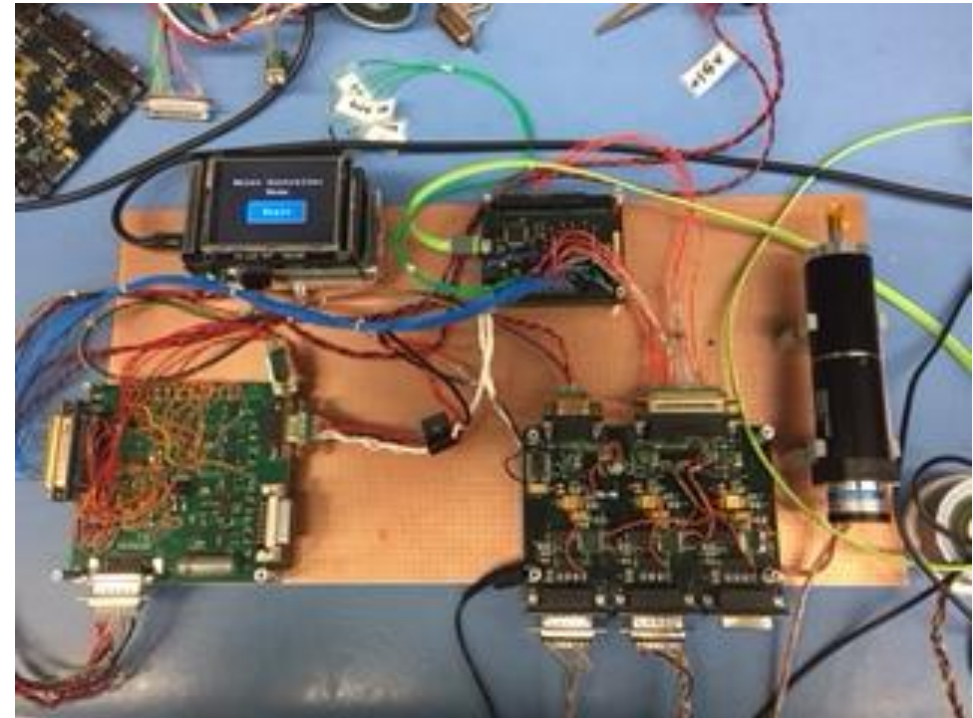


End to End Motor Control Testbed

- Completed construction of second copy of our end to end motor control testbed.
- Testbed includes FPGA, Resolver, Motor Driver and Current sense module breadboards or modules



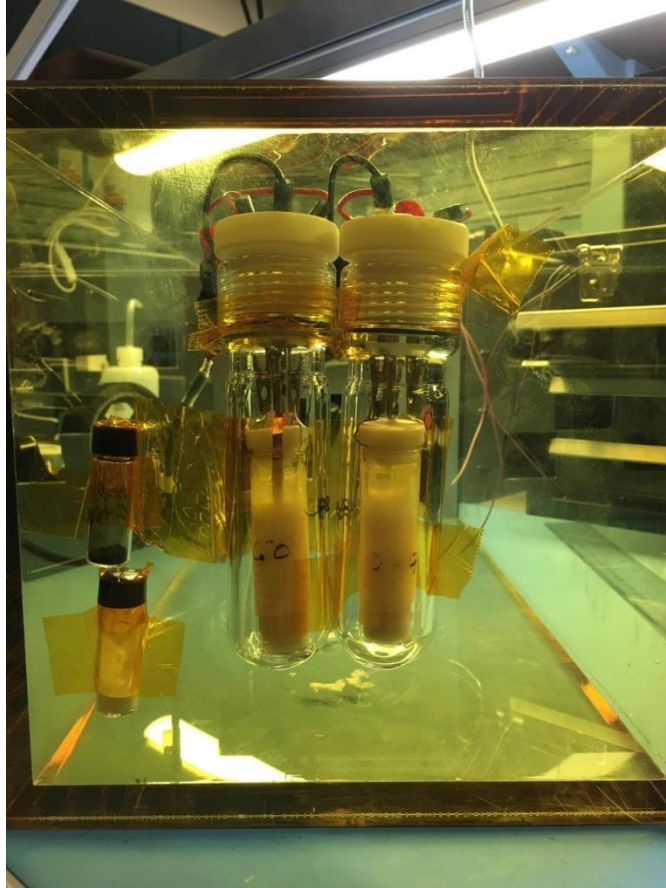
Testbed #1



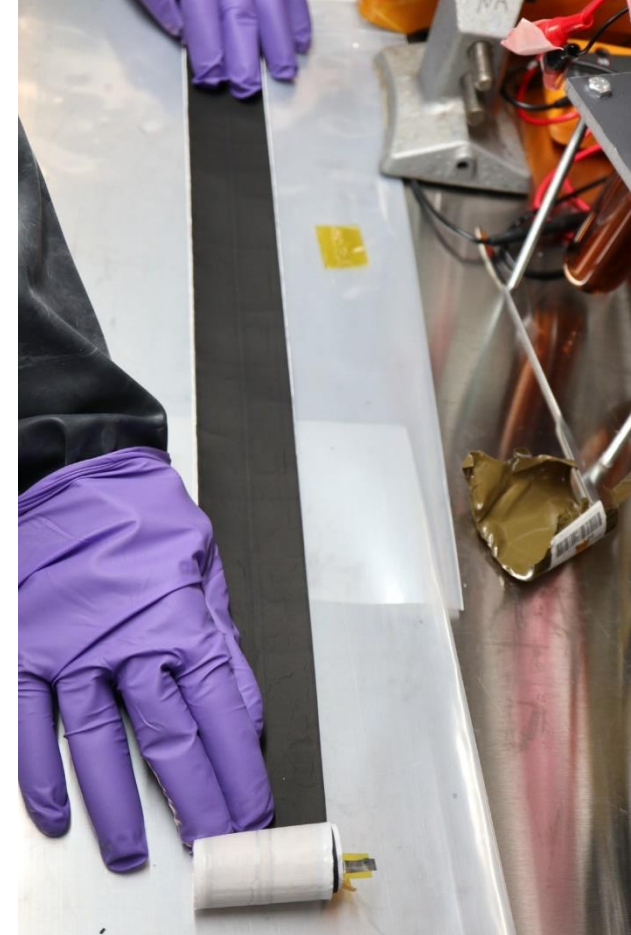
Testbed #2



Battery Development



Irradiated three electrode cells, for evaluation radiation effects on anode and cathode



View of cathode and separator, as jellyroll is unwound during DPA

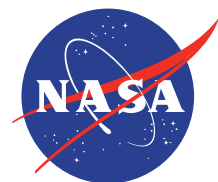


Current Status

- Team is underway working the DTE mission concept and is headed for a Δ -MCR this Fall
- NASA has released ICEE-2 call for development of Instrument Concepts compatible with the Europa Lander Mission Concept
 - Step 1 Proposals due June 22, 2018
- Sampling team testing blades, techniques for sampling cryogenic ice
- DTE antenna panel has been tested
- Radiation testing on Solid Rocket Motor Propellant underway
- Battery environmental testing underway
- Prototype motor controller testbed constructed



Cryo Sampling Test Chamber



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov